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SEAWOLF Digital Data Transfer Program: Implementation of IGES for the Acquisition of a Major Weapons System

MARCH 8, 1991

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DTRC/TM-12-91-05 **8 Mar 1991**

Systems Department
Technical Memorandum

CTN Report 91-004

SEAWOLF DIGITAL DATA TRANSFER PROGRAM: IMPLEMENTATION OF IGES FOR THE ACQUISITION OF A MAJOR WEAPONS SYSTEM

by

Ben Kassel

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Contents

Preface

I acknowledge the following people for their cooperation in identifying the lessons learned in the development and implementation of the SEAWOLF digital data transfer program and contribution to this report: Dan Wooley and Pete Lazo of Newport News Shipbuilding; Greg Morea and Dr. Burton Gischner of General Dynamics, Electric Boat Division; and CDR Blaine Brucker of the SEAWOLF program office.

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Executive Summary

The DoD Computer-aided Acquisition and Logistics Support (CALS) Test Network (CTN) is conducting tests of the military standard for the Automated Interchange of Technical Information, MIL-STD-1840A [1] and its companion suite of military specifications. The CTN is a DoD sponsored confederation of voluntary participants from industry and Government, managed jointly by a technical staff at Air Force Logistics Command (AFLC) and Lawrence Livermore National Laboratory (LLNL). The objective of CTN tests is to demonstrate and evaluate the interchange and functional use of digital technical information between industry and government using the CALS standards.

This document will provide information to organizations which are beginning to implement neutral file database transfers to reduce duplication of effort. The purpose is to educate the CALS community to the efforts and lessons learned in two areas; exchanging drawings using IGES [2] and creating and implementing IGES for the exchange of 3-D design data for piping and structure. Although the efforts of the SEAWOLF Digital Data Transfer Program have been documented in many naval and marine engineering technical journals, there still seems to be a lack of specific knowledge of these efforts in the data exchange community.

1 Introduction

The SEAWOLF is a new class of attack submarine. It is one of the first naval combatants to be designed and constructed primarily using CAD/CAE/CAM/CIM (C^4) technology. Three organizations were involved in the design of the SEAWOLF. The Naval Sea Systems Command (NAVSEA), Newport News Shipbuilding (NNS), and the Electric Boat Division of General Dynamics (EB). Initially the preliminary design was performed by a co-located design team consisting of EB, NNS, NAVSEA, and David Taylor Research Center (DTRC) using CAD facilities at DTRC. Upon completion of a contract design competition, the detail design of non-propulsion areas was awarded to NNS with EB as a subcontractor. The propulsion plant detail design was separately contracted to EB. The first SEAWOLF is currently being built by EB.

The SEAWOLF program evaluated the use of data transfer in all phases of the design and construction. Four major areas were targeted for data transfer; textual data (word processor), processable data (database), engineering drawings (CAD), and product model information (CAD). This discussion deals only with engineering drawings, and product models. For the SEAWOLF program, IGES was selected to transfer CAD data.

2 Design

The SEAWOLF detail design was performed by two different organizations, EB and NNS. NNS was the Lead Design yard, EB is both the Participating Design yard as a subcontractor to NNS, and the Propulsion Plant Design yard. In actual practice, NNS was responsible for the hull and the forward end of the ship. EB was a subcontractor and was responsible for the aft end of the ship.

2.1 Sectional Construction Drawings

SEAWOLF design products include 3D Product Models, System Configuration

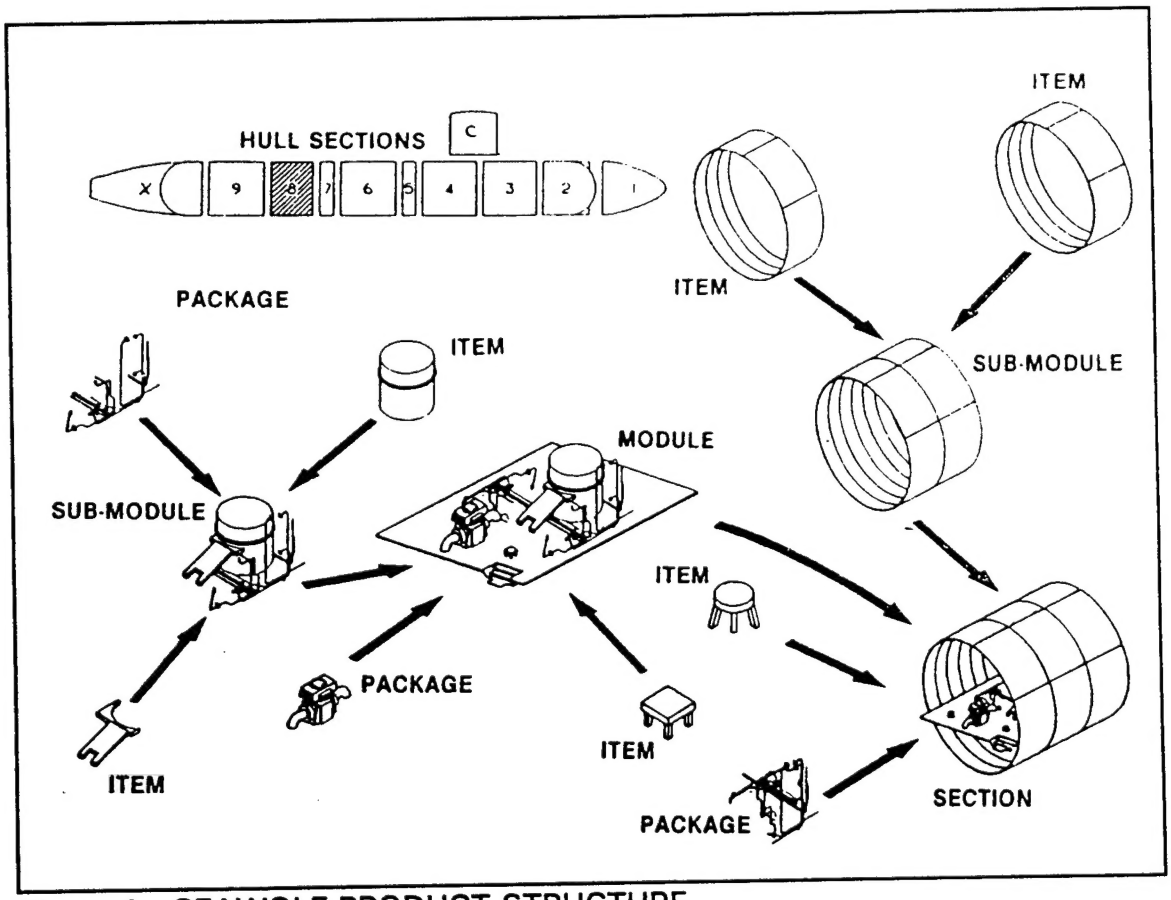

Figure 1 - SEAWOLF PRODUCT STRUCTURE

Drawings, and Sectional Construction Drawings (SCD) for the Class. The SCD's are used as fabrication work packages and as the assembly documents for construction.

The SEAWOLF was designed using Product Structured Drawings. The SEAWOLF implementation of Product Structured Drawings are Sectional Construction Drawings. Each SCD defines an interim product[1] which can also be used as the foundation for a work package [3]. SCD's describe every product defined by the product work breakdown structure. The SCD is subdivided into chapters. The first chapter in an SCD is the control chapter which is the index. Subsequent chapters provide detail information required for construction and installation. For example the SCD for a piping bank which is to be installed into a single unit may be broken down as follows:

Chapter 00 -	Control Chapter
Chapter 31 -	Pipe Manufacturing Details
Chapter 32 -	Hanger Manufacturing and Assembly Details
Chapter 34 -	Assembly
Chapter 35 -	Assembly on Fixture
Chapter 38 -	Fixture Manufacturing Details
Chapter 39 -	Installation

Each chapter is a complete entity in itself containing cover sheet, materials list, notes, references, etc. Lower tier (item or package) SCD's normally create interim products of one classification such as Piping, Ventilation, Structure, Machinery, etc. Because chapters define a specific unit of work, an SCD may not contain every chapter number. All of the IGES files used to transfer product model information are related directly to a chapter of an SCD.

By agreement between the two shipyards and the SEAWOLF program office, each 3D Product Model exchange corresponds to the contents of one of these SCD's. The digital data for the drawings themselves are available for both Configuration Drawings and SCD's.

2.2 Newport News Shipbuilding CAD

The design at NNS is performed using three interfaced CAD systems: VIVID, CADAM

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[1] An interim product is a part or tier of a subassembly which is a component of a larger assembly. It is a product structure based upon Product Work Breakdown Structure (PWBS) and Group Technology. Interim products are combined to create the end product, in this case the SEAWOLF submarine.

3D, and CADAM 2-D. VIVID is a proprietary solid modeling system developed and maintained by NNS. It is used for equipment arrangement, miscellaneous structural design (e.g. foundations and backing structure) and for the design of distributed systems, such as piping, HVAC, and electrical cables. The primary structural systems are designed using CADAM 3D and transferred into VIVID. With all disciplines' solid models co-resident in the VIVID database, VIVID represents the electronic mockup of the design. Engineering drawings originate as views of the VIVID solid geometry, and are transferred to CADAM 2D for annotation and dimensioning. Construction drawings for the partial physical mockup similarly originate in the VIVID model. The interference checking capabilities of VIVID flag potential problems with the design and allow correction before construction drawings are developed. Much of the same distributed system data is later used to feed CAM systems for construction.

2.3 Electric Boat CAD

The design at EB was performed on multiple CAD systems. These consist of commercially available as well as in-house developed systems. PIPER is a proprietary system developed and maintained at EB used to design piping systems. Structural components were designed and nested using Computervision CADDS 4X. Terms of the contract require the maintenance of a full size mockup of certain areas of the submarine. At EB, the mockup is used to determine interferences between structural and distributed systems. EB is currently transitioning to CATIA for all phases of design and construction, however this system has not yet been certified for compliance to digital data transfer procedures.

3 Data Transfer

3.1 Data Transfer Options

Three options were considered by the SEAWOLF program office for data transfer:

1) Require identical systems at each yard.
2) Develop direct translators.
3) IGES

Identical systems at each yard were rejected because of the high cost of new installation and training. Both yards have a great deal of experience, and have dedicated resources to customizing their systems and developing new applications. In addition both yards use systems which have been developed in-house, and it is doubtful that they would want to make their systems available to other shipyards. In the case of the commercial CAD systems, the NAVY would probably be responsible for supplying the CAD systems to the shipyards.

Direct translators were rejected due to the number of different translators which would be required to support the SEAWOLF design and construction. Direct translators imply a conversion between two databases. This would require the developers of the translators to have an intimate knowledge of both systems. In the case of the SEAWOLF this scenario is impossible. It is highly unlikely that the shipyards would participate in a program which would require them to supply details about structure of their proprietary databases. Direct translators are also available in the commercial sector. This was also rejected because of a high set up cost and the rigidity of the translator.

IGES is a neutral format for exchanging CAD application data. The IGES transfer consists of two steps, pre-processing and post-processing. The pre-processor translates the CAD database to IGES and the post-processor translates an IGES file to a CAD database. The interim product (IGES file) is independent of any proprietary format, and is in a readable, standard format. This reduces the number of translators which must be supported for a finite number of CAD systems as shown in Figure 2.

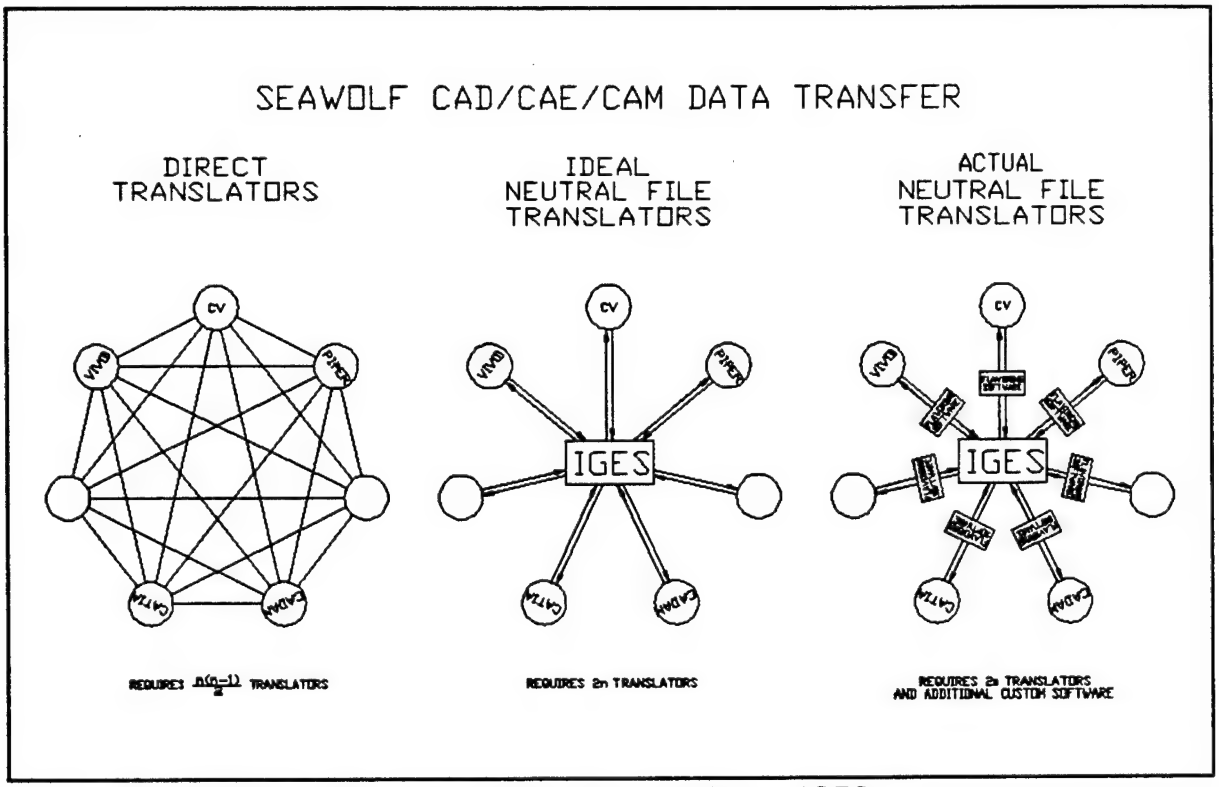

Figure 2 - AMOUNT OF TRANSLATORS: DIRECT vs IGES

The SEAWOLF program enhances the commercial IGES translators with additional flavoring[2] software. Flavoring software can be used during pre-processing or post-processing. It compensates for deficiencies in the translators and IGES. As these deficiencies are resolved the flavoring will no longer be required.

3.2 Data Transfer Program

The SEAWOLF data transfer program was started in 1985. The SEAWOLF program selected IGES [4] to transfer CAD data between the design yards, shipbuilders, planning yard, and NAVSEA. The immediate concern was the transfer of drawing sheets, structural models, and piping models between the lead design yard and the lead shipbuilder. The data transfer program consisted of four working groups and a guidance committee. An organizational chart is shown in Figure 3. Although the SEAWOLF program includes non-processable textual data and processable textual data, only data which can be exchanged using IGES will be discussed. IGES is being

[2] Flavoring software is used to modify the IGES file during pre-processing or post-processing. It is used to compensate for deficiencies in the CAD package or IGES translator.

used to transfer a digital representation of drawings, and the product model, between CADAM Release 21 and Computervision CADDS 4X REV 6.0, as well as PIPER and VIVID. Two working groups were established to develop the CAD data exchange program. Working group C is responsible for engineering drawings and working group D is responsible for product models. Separate working groups were established because the requirements and issues of transferring drawings and product models are very different[3]. Although two separate groups are involved, continuity is provided by some of the same members participating in both groups.

3.3 Organization

Each working group was kept small, and initially consisted of representatives from the SEAWOLF program office, NNS, EB, as well as a NAVSEA contractor responsible for administrative tasks.

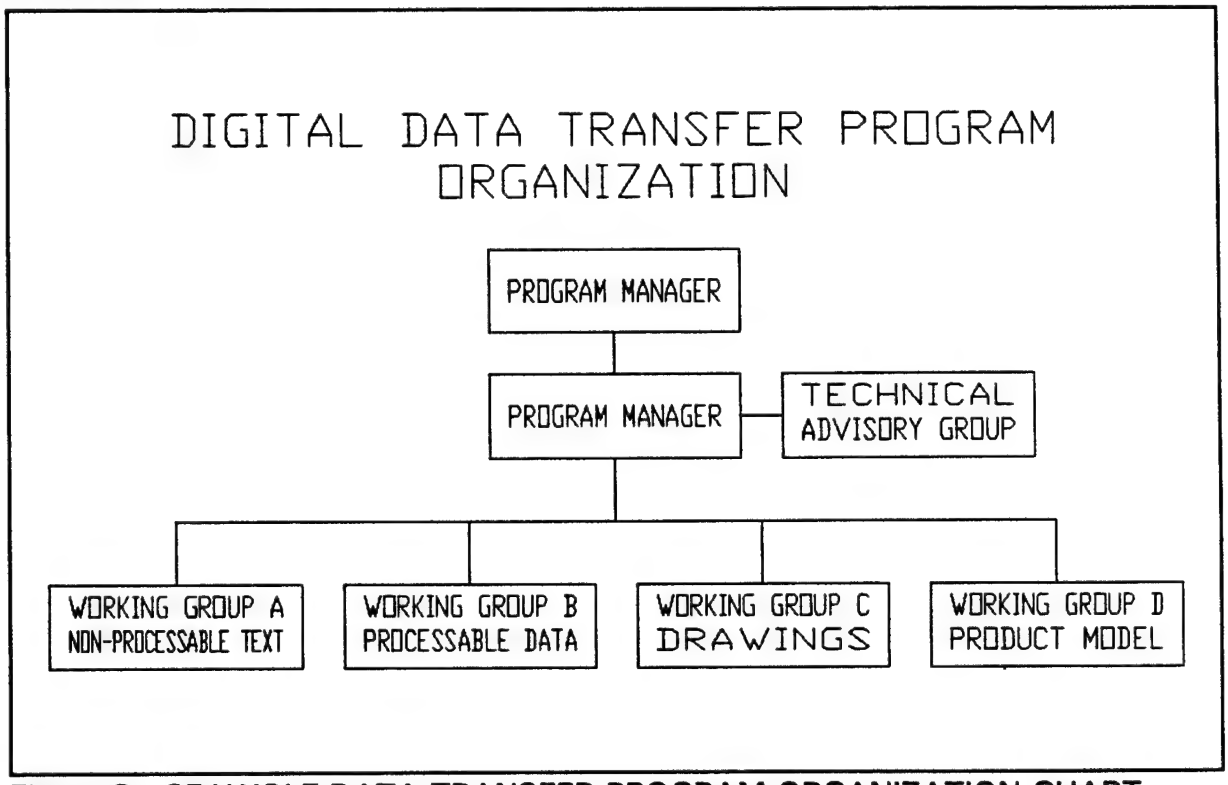

Figure 3 - SEAWOLF DATA TRANSFER PROGRAM ORGANIZATION CHART

[3] Geometry is well defined because there are few ambiguities when translating between native CAD and IGES constructs. On the other hand graphics such as text fonts, line fonts, arrowheads, and crosshatching are very different between CAD systems.

The chairmen of the working groups are shipyard employees, and the chairman of the guidance committee is a SEAWOLF program office employee. The guidance committee provides direction to the working groups, and answers directly to the SEAWOLF program manager. During the early stages of the data transfer program, the SEAWOLF program office also had a technical representative observe the meetings and review the progress of the working groups. The technical advisor was an experienced CAD user who had a working knowledge of IGES and some familiarity with the CAD systems. During these meetings the number of people in attendance would vary, up to twenty five people could be in attendance at these meetings. In fact, at some of the meetings the observers greatly outnumbered the participants.

3.3.1 Data Transfer Working Group 'C'

Working Group 'C' was established to address the transfer of drawings using IGES. The first step undertaken by Working Group 'C' was to determine the domain of the transfer. NNS used CADAM 2D to create drawings generated from the product model (VIVID) and EB used CV to generate drawings. Therefore, it was decided to limit the domain of the SEAWOLF digital drawing transfer program to CADAM 2D and CV. In addition, other issues needed to be addressed including modeling techniques, coordinate systems, shipyard specific procedures, etc. When the group was formed Version 2.0 of IGES was used, with the understanding that the procedures, software, and translators would be updated as subsequent versions of IGES were released.

3.3.2 Data Transfer Working Group 'D'

Working Group "D" is responsible for the transfer of digital representation of the product model using IGES. When the group was formed Version 2.0 of IGES was used, with the understanding that the procedures, software, and translators would be updated when new and improved versions become available. Currently, Version 5.0 is being used. The first problem was to define the product model. The working group agreed the product model cannot be defined to the satisfaction of both yards, and still be transferable using IGES in its current form. The decision was made to divide the product model into a structural model, and a piping model. These two applications were selected because they provided the highest payback potential. Two separate data transfer procedures would be prepared. This project required minor enhancements to the Computervision and the CADAM IGES translators for structural

exchange as well as the development of translators to the proprietary systems used for the design of piping systems. The translators developed[4] for the SEAWOLF program adhere strictly to IGES so the resulting neutral files will be compatible with commercial CAD translators when they are released.

3.4 CAD Vendor Interaction

As with most users of CAD systems, the SEAWOLF program was dependent on the CAD vendors to implement enhancements and resolve bugs. Representatives of the CAD vendors attended many of the data transfer meetings. Most of the requests for enhancements were implemented by the CAD vendors, and all of the bugs were acknowledged. To this day some anomalies remain which have not been resolved. Some of these problems are due to the CAD packages, not the IGES translators. The major problem with the CAD vendors is the response time. This is however understandable, as the CAD vendors must comply with a release schedule which includes much more than the data transfer applications. Special point releases of the CAD vendors software (beta) were issued to the shipyards in order to address modifications as a direct result of SEAWOLF. It must be stressed that the modifications to the IGES translators by the CAD vendors were incorporated into their commercial product. **THE ENHANCEMENTS DEVELOPED BY THE CAD VENDORS WERE NEITHER PROJECT UNIQUE NOR NAVY UNIQUE SOFTWARE!** The users of the package must have a good working relationship with the CAD vendor or be willing to dedicate the resources required to modify the IGES interface, which defeats one of the purposes of using commercial CAD.

In many cases the CAD vendor appeared uncooperative and gave the impression that the required modifications would require major revisions to the product. At the next meeting this same vendor had resolved the issue and a fix would be released in the next revision. There were however some enhancements which were not made. When this situation occurred the relationship with the CAD vendor is very important because the CAD vendor may be able to provide assistance or give advice in the development of a workaround. In cases where the problem is beyond the vendors

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[4] Translators were only developed for CAD systems developed and maintained by the shipyards in-house. Translators for the commercial CAD systems were enhanced and maintained with input provided by the SEAWOLF program office, EB, and NNS. There was no direct cost to the NAVY for enhancement and maintenance of the commercial CAD software.

control, or they choose not to follow the recommendation of the group, custom software must be written. The software includes pre- and post-processors, as well as routines which modify the CAD system database.

3.5 Translation Discrepancies

A translation discrepancy occurred whenever something unexpected happened. In the early stages of the program these discrepancies were used to determine how the processors and IGES should be enhanced. As the program entered into the production transfer of data the translation discrepancies were used to determine the condition of the data and its conformance to the digital data exchange procedures. Translation discrepancies fall into five classes:

1) Pre-processor
2) Post-processor
3) IGES
4) System differences
5) User errors

The Pre-processor and Post-processor are taken care of by the developers of the CAD package. In some cases the vendor felt the discrepancy was not caused by the CAD software. This could require the development of new procedures, an IGES request for change (RFC) or the development of flavoring software. The SEAWOLF program also uncovered problems with IGES. EB, NNS, and NAVY participants were all working members of the IGES/PDES Organization (IPO) and worked with the vendors, IGES members, and the National Institute of Standards and Technology (NIST) through the submission of RFC's and the development of recommended practices. System differences were taken care of by the development procedures and flavoring software, as well as the recognition of prohibited and restricted entities. In any design and data transfer program there is always the probability of user errors.

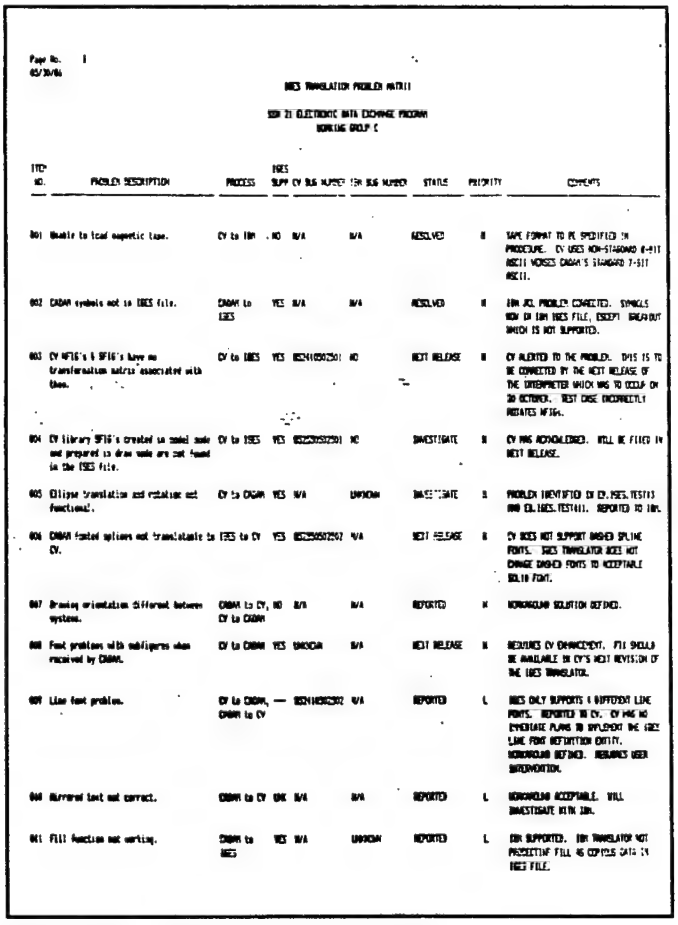
3.6 Restricted and Prohibited Entities

The use of certain types of entities need to be controlled due to the differences between the CAD systems, modeling practices, problems with the translators, and ambiguities caused by IGES. For this program, these entities were classified into two

categories, restricted use entities and prohibited entities. A restricted use entity cannot be transferred identically in the IGES exchange process between the two shipyards. It is recommended that the use of these entities be kept to a minimum. A list of restricted entities is provided in Appendix A. This list of entities is regularly reviewed and revised as part of the maintenance procedures of the digital drawing exchange procedure.

3.7 Data Transfer Issue Documentation

Both of the working groups were responsible for documenting and tracking data transfer issues. An issue is any item which impedes the transfer of data between CAD systems. In order to create and maintain a data transfer procedure the history of the problem and its solution must be recorded. A problem matrix was developed to document the status of each problem.



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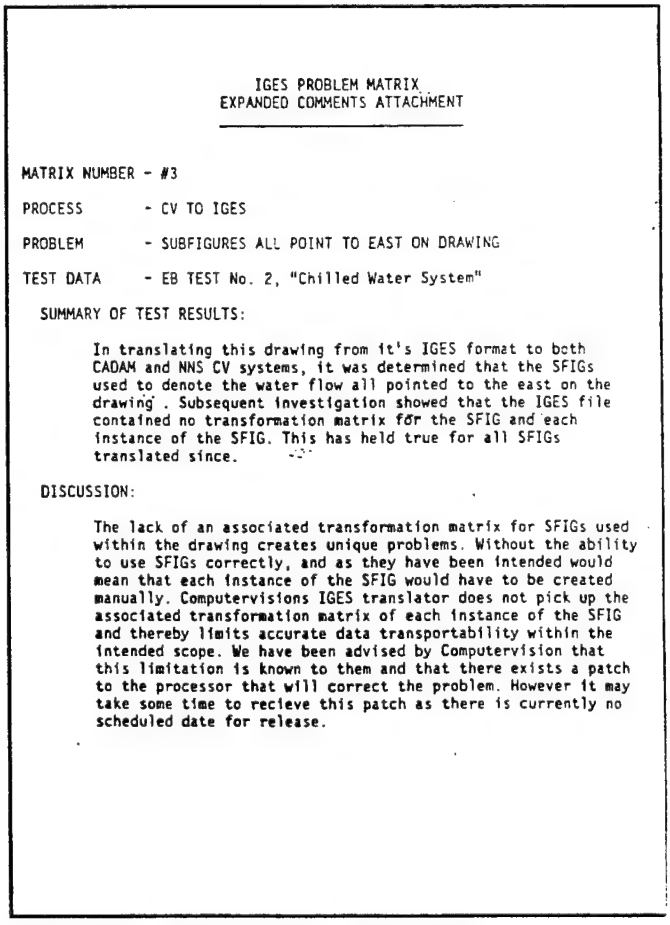
IGES TRANSLATION PROBLEM MATRIX

NSH 21 ELECTRONIC DATA EXCHANGE PROGRAM
WORKING GROUP C

ITEM NO.	PROBLEM DESCRIPTION	PROCESS	IGES SUPP	CV IGS NUMBER	FOR IGS NUMBER	STATUS	PRIORITY	COMMENTS
001	Unable to load magnetic tape.	CV to IBM	NO	N/A	N/A	RESOLVED	H	TAPE FORMAT TO BE SPECIFIED IN PROCEDURE. CV USES NON-STANDARD 8-BIT ASCII VERSES CADAM'S STANDARD 7-BIT ASCII.
002	CADAM symbols not in IGES file.	CADAM to IGES	YES	N/A	N/A	RESOLVED	H	IBM JCL PROBLEM CORRECTED. SYMBOLS NOW IN IBM IGES FILE, EXCEPT BREAKOUT WHICH IS NOT SUPPORTED.
003	CV NFIG's & SFIG's have no transformation matrix associated with them.	CV to IGES	YES	0024105025D1	NO	NEXT RELEASE	H	CV ALERTED TO THE PROBLEM. THIS IS TO BE CORRECTED BY THE NEXT RELEASE OF THE INTERPRETER WHICH WAS TO OCCUR ON 30 OCTOBER. TEST CASE INCORRECTLY ROTATES NFIG#.
004	CV library SFIG's created in model mode and prepared to draw mode are not found in the IGES file.	CV to IGES	YES	0025050250D1	NO	INVESTIGATE	H	CV HAS ACKNOWLEDGED. WILL BE FIXED IN NEXT RELEASE.
005	Ellipse translation and rotation not functional.	CV to CADAM	YES	N/A	UNKNOWN	INVESTIGATE	H	PROBLEM IDENTIFIED IN CV.IGES.TEST13 AND CV.IGES.TEST411. REPORTED TO IBM.
006	CADAM fonted splines not translatable to CV.	IGES to CV	YES	0025050250Z	N/A	NEXT RELEASE	H	CV DOES NOT SUPPORT BROKEN SPLINE FONTS. IGES TRANSLATOR DOES NOT CHANGE BROKEN FONTS TO ACCEPTABLE SOLID FONT.
007	Drawing orientation different between systems.	CADAM to CV, CV to CADAM	NO	N/A	N/A	REPORTED	H	WORKAROUND SOLUTION DEFINED.
008	Font problems with subfigures when received by CADAM.	CV to CADAM	YES	UNKNOWN	N/A	NEXT RELEASE	H	REQUIRES CV ENHANCEMENT. FIX SHOULD BE AVAILABLE IN CV'S NEXT REVISION OF THE IGES TRANSLATOR.
009	Line font problem.	CV to CADAM, CADAM to CV	—	0024105025D2	N/A	REPORTED	L	IGES ONLY SUPPORTS 4 DIFFERENT LINE FONTS. REPORTED TO CV. CV HAS NO IMMEDIATE PLANS TO IMPLEMENT THE IGES LINE FONT DEFINITION ENTITY. WORKAROUND DEFINED. REQUIRES USER INTERVENTION.
010	Mirrored text not correct.	CADAM to CV	IGNORE	N/A	N/A	REPORTED	L	WORKAROUND ACCEPTABLE. WILL INVESTIGATE WITH IBM.
011	Fill function not working.	CADAM to IGES	YES	N/A	UNKNOWN	REPORTED	L	IBM SUPPORTED. IBM TRANSLATOR NOT PRESENTING FILL AS COMPLEX DATA IN IGES FILE.

Figure 4 - PROBLEM MATRIX



IGES PROBLEM MATRIX
EXPANDED COMMENTS ATTACHMENT

MATRIX NUMBER - #3

PROCESS - CV TO IGES

PROBLEM - SUBFIGURES ALL POINT TO EAST ON DRAWING

TEST DATA - EB TEST No. 2, "Chilled Water System"

SUMMARY OF TEST RESULTS:

In translating this drawing from it's IGES format to both CADAM and NNS CV systems, it was determined that the SFIGs used to denote the water flow all pointed to the east on the drawing . Subsequent investigation showed that the IGES file contained no transformation matrix for the SFIG and each instance of the SFIG. This has held true for all SFIGs translated since.

DISCUSSION:

The lack of an associated transformation matrix for SFIGs used within the drawing creates unique problems. Without the ability to use SFIGs correctly, and as they have been intended would mean that each instance of the SFIG would have to be created manually. Computervisions IGES translator does not pick up the associated transformation matrix of each instance of the SFIG and thereby limits accurate data transportability within the intended scope. We have been advised by Computervision that this limitation is known to them and that there exists a patch to the processor that will correct the problem. However it may take some time to recieve this patch as there is currently no scheduled date for release.

Figure 5 - EXPANDED MATRIX

The problem matrix contains:

- problem item number
- problem description
- responsibility
- status
- priority
- comments

Expanded comments about each entry in the problem matrix supplies specific information about the problem. An example of the problem matrix is shown in Figure 4, and a typical problem matrix expanded comment is shown in Figure 5.

3.8 Digital Data Exchange Procedures

A digital data exchange procedure (DDEP) was developed for each of the data transfer programs. The DDEP defines all of the procedures, including the actual CAD systems and translators certified for transferring production data. Whenever any of these components are changed the baseline test cases must be processed and evaluated. Upon successful completion of the test cases the DDEP is revised.

3.8.1 Development of the Data Exchange Procedures

Finally, when the CAD vendors have fixed bugs, and provided enhancements, and the shipyards have written and tested custom software the procedure manual can be finalized. This document was the final product of the working group, and contains information about:

- TERMS AND DEFINITIONS
- TAPE AND FILE FORMAT
- DRAWING REQUIREMENTS
- DATA SEGREGATION
- EXCHANGE PROCESS
- LIMITATIONS
- WORKAROUNDS
- PROCEDURE MAINTENANCE

The Lead Design yard is responsible for maintaining the procedures which will be revised if changes to IGES or the translators affect the data transfer process. The working groups still exist as a maintenance committee, and if the procedure requires major modifications then the working group will be formed again to solve the problems.

3.8.2 Digital Product Data Control Manual

This procedure [5] controls and documents the exchange of SEAWOLF CAD data. This includes drawings, structural product models, and piping product models. This document applies to all CAD data exchanges and defines:

- Approved CAD applications and versions
- Tape and file formats
- Unit of exchange
- Data availability
- Frequency of data exchange
- Exchange Procedures
- Problem resolution
- Data Retention

3.8.3 Digital Drawing Exchange Procedure

This procedure [6] controls the exchange of digital drawings. It documents specific information about the drawing transfer including the CAD software and translator version certified for the SEAWOLF program. It augments the Digital Product Data Control Manual by providing additional information unique to the transfer of drawings including:

- Prohibited and restricted entities
- Workarounds
- Maintenance of the Digital Drawing Exchange Procedure
- Specific IGES processing instructions
- Quality Assurance Procedures
- Descriptions of flavoring software

3.8.4 Structural Data Exchange Procedure

This procedure [7] controls the exchange of structural product models. It documents specific information about the transfer of plates and rolled structural sections. It augments the Digital Product Control Manual by providing additional information unique to the exchange of structural product models including:

- Coordinate system
- IGES data tolerances
- Geometric entities
- Non-geometric entities
- Modeling techniques
- Maintenance of the Manual Describing Content and Format of Plate and Rolled Section Structural Transfer
- Descriptions of flavoring software

The Exchange of structural data requires geometric as well as non-geometric data. Because IGES does not provide any guidance as to how geometry and attributes should be combined to represent product data those relationships have been defined in this procedure.

3.8.5 Piping Data Exchange Procedure

This procedure [8] controls the exchange of piping product models. It augments the Digital Product Control Manual by providing additional information unique to the exchange of piping product models including:

- Pipes
- Joints
- Pipe Runs
- Attachments
- Stave Damping Assemblies
- Pipe Hangar Locations
- Components

This procedure uniquely describes piping concepts in terms of IGES entities. It

provides all of the information required to build an application specific IGES translator. It is important to realize this procedure is only applicable to CAD systems and applications which deal with pipe systems.

3.9 Drawing Transfer

Originally it was thought that the biggest payback would be the transfer of drawings between the design agent and the shipbuilder. A great deal of effort was dedicated to assessing the ability of the CAD systems to exchange drawings using IGES. Working Group "C" was established to determine the type of drawings to be transferred, and to develop procedures to transfer the data as well as to manage the data. The SEAWOLF program was required to develop an end to end exchange[5] capability.

3.9.1 Development of the Drawing Data Transfer Program

Initially, an overview of both participating CAD systems was presented to provide background information. A pilot test was initiated in order to determine the magnitude of effort required to transfer a complete drawing. After evaluating the initial tests, a milestone chart was established. The major milestones were:

- PILOT TEST 1
  - DESIGN TESTS
  - EVALUATION
- PILOT TEST 2
  - DESIGN TESTS
  - EVALUATION
  - DEVELOP WORKAROUNDS
- FINALIZE BENCHMARK
- ISSUE EXCHANGE PROCEDURE

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[5] End to end data transfer refers to a known source and target system and consists of two specific processes. The source system pre-processor creates the IGES file and the post-processor translates the IGES file into data useable on the receiving system. The end to end transfer is usually the goal of most data transfer programs due to the limited number of CAD systems involved as well as the complexity of developing a generic testing and quality assurance program.

Pilot test 1 consisted of the transfer of production drawings representing different aspects of detail design. Upon evaluating the initial tests, several problems were identified with the transfer process. New tests were developed which would examine these problems in detail. A scheme for evaluating the transfer process was then developed. The results of the tests were discussed at monthly meetings of the working group. Most problems were related to the translators, and differences between the CAD systems. Depending upon the evaluation of the test cases at the monthly meeting, new test cases would be proposed. Each shipyard would develop a test case to demonstrate the problem, perform a loop test[6], send the IGES file to the other shipyard to be post-processed, and a copy to the SEAWOLF program office. These test cases were cataloged and will be used to evaluate subsequent versions of the CAD software, IGES, and the procedure manual. This will allow the problems to be isolated, and solved; and the fix, or workaround could be tested on a production part. In some instances where the problem was non-trivial, or difficult to isolate, a splinter group was formed consisting of one or two representatives of each shipyard, and possibly one from the SEAWOLF program office. This involved one or two days studying the problem, and proposing a fix. The findings of the splinter group were discussed at the next working group meeting.

3.9.2 Transfer Quality

Quality of the transfer for engineering drawings was difficult to assess, and must be divided into two categories; functional equivalence and graphical equivalence. Unfortunately one of the SEAWOLF lessons learned is graphical equivalence is extremely difficult to achieve, and the relative payback is low. In the implementation of vector data translation, functional equivalence is more important. What may be perceived as a successful data transfer by the CAD user may be interpreted as a failure by upper level management. An excellent example of the difference between functional and graphical equivalence involves the exchange of filled text between CADAM and CV. In this case CV does not support filled text, and therefore graphical equivalence is lost. However the text is treated as a single entity in the CV system and can be edited. For graphical equivalence to be achieved the text must be stroked

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[6] A loop test consists of pre-processing and post-processing the IGES file on the same system. This does not add any value to the transfer process but is used to reveal gross errors in the translator, and to debug the test case. In many cases the loop test will fail to reveal errors because the post-processor compensates for the pre-processor deficiencies.

and the interior crosshatched. This will increase the entity count and size of the database. In addition, the resulting text cannot be edited. Other problem areas include line and text fonts, line thicknesses, arrowheads, in other words, most of the annotation entities.

3.10 Product Data Transfer

3.10.1 Exchange of Structural Data

Structural models are developed by EB using CV, and by NNS using CADAM 3D. The working group needed to determine which portion of the product model as well as the level of information to be transferred. The working groups decided to transfer data which was available at both design yards. This would allow productive transfer at the least cost, because data produced in the normal course of detail design development at each yard could be used, with minimal impact on the two organization's design practices.

The content of structural exchanges was limited to flat and rolled plates and shapes. Incompatibility between surface modeling capabilities on the two CAD systems prevented exchange of castings or forgings.

Three levels of data were considered for exchange: fabrication level, 3D design part level, and 'high' level.

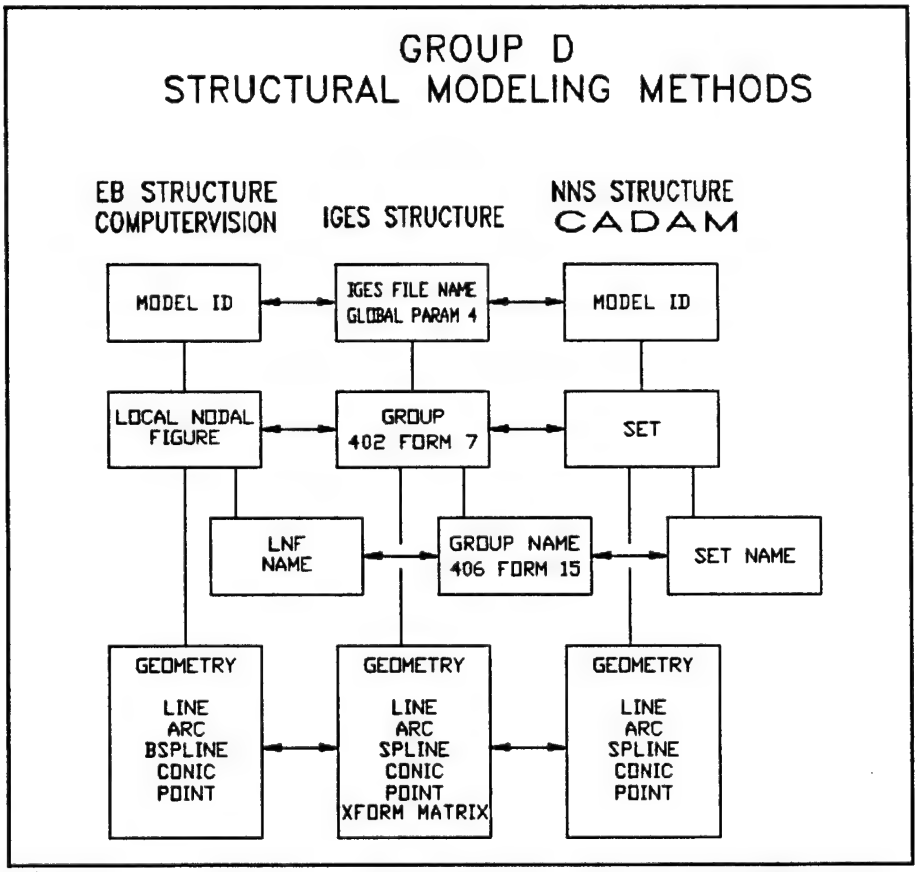

Figure 6 - GROUP D STRUCTURAL MODELING METHODS

Fabrication level would consist of nested plates ready for Numerical Control burning at either site. Because of yard-specific lofting practices and the fact that the cost of developing this fabrication information was outside of the scope of the detail design contracts, this option was rejected. 'High' level design information would have transferred intelligent compressed design information for regeneration at the receiving site. The use of a 'high' level exchange mechanism would have required replacement or major modification to both yards' CAD systems for the SEAWOLF design, and thus was also rejected. The chosen level of data representation for exchange was 3D design parts. CV and CADAM 3D produce very similar 3D wireframe models, and both yards intended to develop these models as part of the normal course of detail design. Little additional design work would be needed to allow digital exchange of the data, and the existing CAD systems at both yards could be used.

The transfer of structural data utilized commercial IGES translators supplemented by procedures [5]. These procedures provide additional guidance for interpreting the IGES file. The exchange of structural information required the shipyards to translate CAD system constructs to the IGES entity types selected by the members of the working group.

Wireframe geometry representing all edges of each part, including any holes, are exchanged using IGES entities 100 (circular arc), 104 (conic arc), 110 (line), 112 (parametric spline), 116 (point), and 126 (B-spline). IGES entity 124 (transformation matrix) is used to locate the geometry in 3D model space. The IGES 402 Form 7 (group associativity) entity is used to group together all the geometric entities which represent a single plate or shape. The Group Associativity points to a IGES 406 Form 15 (Name property), which carries the part's unique drawing find number. Figure 6 illustrates the mapping from CV and CADAM 3D to IGES.

3.10.2 Exchange of Piping Systems Data

Piping models are developed at EB using PIPER, and at NNS using VIVID. The exchange of piping data was more complex than for structural data, however the shipyards had more control over the transfer because they had developed the CAD system and the IGES translators. The piping systems exchange was developed in two phases. Phase 1 consisted of pipe pieces and pipe joints. Phase 2 included joints, one, two, and three ended components in the piping run, stave damping assemblies,

and hanger locations. Piping data is transferred for all exchangeable piping piece parts sourced by the applicable SCD drawing and find number in the engineering parts list.

Standard IGES entities are used to represent 3D piping data. The format and content of the IGES is specific to piping applications. The specific IGES entities used to represent piping data as well as its usage is provided in the Piping Data Exchange Procedure. Since standard IGES entities are used to describe 3D piping data, parts of the IGES file may be post-processed by general purpose CAD systems. For example, the definition of the centerline of a pipe is defined by wireframe geometry and a composite curve. In the event more information is required, software will have to be developed to post-process the IGES file in the context defined in the Piping Data Exchange Procedure.

4 Test Cases

A major amount of the effort was in the development, processing, and interpretation of the test cases. The maintenance and quality control of the translators was dependent upon the test cases. Every time a new version of CAD software or IGES translators is issued the baseline test cases are processed and the procedures are modified before it can be used in the production environment for the SEAWOLF. Test cases were developed for the transfer of drawings, structural models, and piping models. Each test case is designed to test a specific concept.

4.1 Drawing Test Cases

The first step consisted of transferring production drawings to serve as a baseline in order to determine what problems would be encountered. It was not surprising to encounter problems relating to:

- Translators
- System Differences
- Design Practices
- IGES

To isolate the problems, small special case test drawings were created on one system, and a loop test was performed. The IGES text file, a hard copy of the drawing, and the results of the loop test were sent to the SEAWOLF program office, and the other yard. Each shipyard created test cases to exercise its CAD system and IGES translators. These initial test cases revealed some issues which would have to be resolved in order to effect a quality transfer of data. The next set of test cases were developed to investigate these issues. Test cases were developed to evaluate CAD system entities and concepts such as view visibility, blanking, layering, clipping, etc. A list of the test cases developed to test the drawing exchange is described in Appendix A.

4.2 Structural Test Cases

The unmodified, commercially available, IBM and Computervision IGES translators

successfully fulfilled the required exchange capability for structural model data to a much greater degree than they fulfilled the drawing data exchange requirements. At NNS, minor additional flavoring was needed to accomplish the translation of piece part names on each CADAM 'set' into the IGES entity chosen for the exchange. No flavoring was needed on the CV system.

As few problems were encountered with the off-the-shelf translators, detailed entity-specific test cases, similar to those developed for drawing exchange testing, were not necessary. Test cases were chosen from existing data on each of the CADAM and CV systems to exercise the exchange capability and to provide a baseline for any future changes to hardware or software.

The original structural test cases consisted of a simple foundation model and a large, more complex, tank model from each shipyard's CAD system. These were used for baseline testing of production exchanges through mid-1990. Due to increased use of the test cases outside of the SEAWOLF Program (e.g., by other CALS Test Network members), NNS replaced their test cases in 1990 to circumvent any potential security concerns over wide release of 'real' ship data.

The two new NNS test cases consist of a simple stiffener model and a more complex, though imaginary, bulkhead and shell assembly. The stiffener model tests each element type allowed in the production SEAWOLF exchanges (lines, arcs, ellipses, and splines). The more complex model tests the allowed entity types, the various standard line fonts and weights available on the CADAM system, color, and the merging of multiple CADAM models into a single exchangeable IGES file.

The current SEAWOLF baseline test suite is composed of the two new NNS test cases and the original EB foundation and tank models. A list of the test cases developed to test the exchange of structure is described in Appendix B.

4.3 Piping Test Cases

The piping data transfer program was implemented in two phases, phase I consists of pipe pieces. Phase II will include:

- Pipes
- Joints
- Pipe Runs
- Attachments
- Stave Damping Assemblies
- Pipe Hangar Locations
- Components

The phase I test cases verify the ability of the translator to create the necessary IGES entities for representing straight pipe pieces, pipes with bends, as well as accurately locating pipes in ship's coordinates. These test cases are now of limited value, but will remain part of the baseline.

The phase II test cases verify the ability of the translator to create the necessary IGES representations for representing each type of **piping** entity developed for the exchange. These test cases include a complex piping system consisting of each type of piping entity developed for the exchange. This set of test cases also verifies the relationship between the piping model and the SCD.

A list of the test cases developed to test the exchange of piping systems is described in Appendix C.

5 Exchange of Production Data

The exchange of production data is governed by the digital data exchange procedures. These procedures were referenced by the SEAWOLF design and construction contracts. The exchange of digital drawings is performed on a per request basis. The exchange of piping and structural product models are made automatically within ten working days of the corresponding SCD issue date by the Design yard. The data is exchanged using 1/2" 9 track magnetic tape. MIL-STD-1840A is not used because the SEAWOLF data transfer program was initiated before the standard was mandated. The IGES files are written to tape as ASCII files. The tape is sent with a SEAWOLF Digital Data Exchange Transmittal Form shown in Figure 7. For drawings, an entity notification report which documents all of the "restricted use" entities in the IGES file is also sent. The IGES file is subjected to QA at the receiving site. This includes an evaluation of the compliance of the IGES file to the applicable digital data exchange procedure. In the event of an undocumented problem with the tape or any of the data, the receiving shipyard issues a translation discrepancy report. This provides the sending shipyard and the SEAWOLF Program office with a description of the discrepancy, details about the discrepancy, and an evaluation of the probable cause, plots, and a printout of the IGES file. Upon review by both shipyards and the SEAWOLF program office the cause of the discrepancy is

SEAWOLF DIGITAL DATA EXCHANGE TRANSMITTAL FORM

ESWBS NO.: 834

SENDER:	RECEIVER:
DAN WOOLEY DEPARTMENT E11 NEWPORT NEWS SHIPBUILDING 4101 WASHINGTON AVENUE NEWPORT NEWS, VIRGINIA 23607	BEN KASSEL DTRC CODE 1851 BETHESDA MD 20084

TRANSMITTAL NO.: NNDRCTPT00017		REQUEST NO.: N/A
DATE: 12/10/90	NO. TAPES: 1	PROCESSOR: ITS R3.0
DATA TYPE: PIPING		

DRAWING NO.	DWG REV	SHT NO.	SHT/PD REV	TAPE NO.	COMMENTS (OPTIONAL)
BASELN-H			A	1	PIPING DATA EXCH BASELINES
BASELN-1A			A	1	
BASELN-1V			A	1	
BASELN-02			A	1	
BASELN-03			A	1	
BASELN-04			A	1	
BASELN-5A			A	1	
BASELN-5B			A	1	
BASELN-5C			A	1	
BASELN-5D			A	1	
BASELN-5E			A	1	
BASELN-5F			A	1	
BASELN-06			A	1	

SHEET (1) OF (1)

Figure 7 - TRANSMITTAL FORM

established, and is added to the problem matrix.

All drawings contain a "Computerized Reproducible Master" symbol. During the pre-processing, an IGES symbol is inserted automatically. This is used to differentiate between the original drawing, and the post-processed drawing. The symbols are shown in Figure 8 and 9.

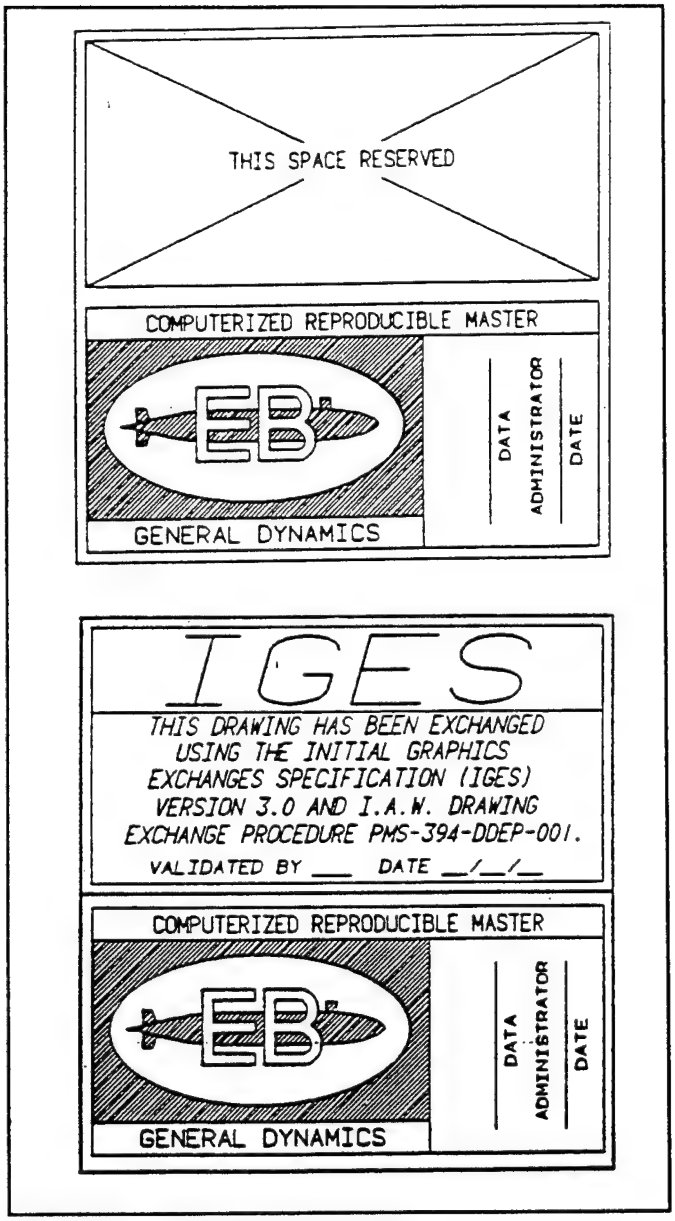

Figure 8 - EB CRM SYMBOL

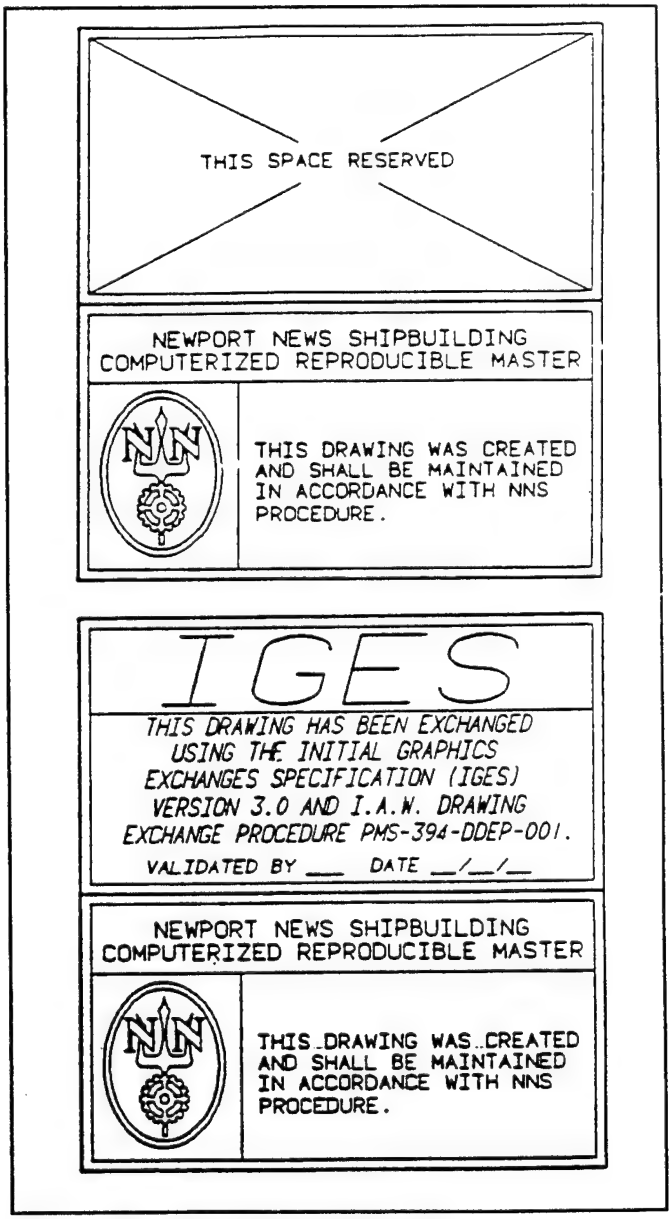

Figure 9 - NNS CRM SYMBOL

6 Standards Development

The SEAWOLF program is involved in the development of standards for the exchange of drawings and product models. Both shipyards are working members of the IGES/PDES Organization (IPO) and charter members of the NAVY/Industry Digital Data Exchange Standards Committee (NIDDESC). In addition NNS and General Dynamics are both members of PDES Inc.

6.1 NIDDESC

NIDDESC is a cost sharing cooperative effort involving Navy and Industry experts who seek to avoid the regeneration of databases by enabling the exchange of digital data between successive agents during the ship's life cycle. NIDDESC efforts focus on the development of an assured data transfer capability through the creation of a Navy/Marine Industry digital data transfer specification. These specifications will define explicit formats for the transfer of digital data between the Navy and Marine Industry. Specifications are developed through the consensus of Navy and Marine industry participants and are based on the Product Data Exchange using Step (PDES) file format.

6.2 MIL-D-28000

The SEAWOLF program was instrumental in the development of the 3D IGES Piping Application Protocol (AP) [9]. This will be the first AP to be included in MIL-D-28000. The Piping AP is used to exchange arrangement data of 3D piping systems. This AP was based upon the SEAWOLF piping data exchange program. Additional review and requirements were provided by representatives of process plant, chemical, and petroleum industries.

An IGES AP is being developed for the exchange of drawings and the corresponding 3D wireframe model (Engineering Drawing Level 2 AP). EB is being sponsored by NIDDESC to coordinate efforts between industry and government to develop the AP. Many of the requirements have been obtained from the SEAWOLF program. In addition efforts are being coordinated with Level 1A and STEP AP development. Ultimately this AP will include surface and solid geometry.

7 Future Directions

The SEAWOLF data exchange program was considered successful enough by Design and Construction managers that a study of additional efforts was conducted. The study indicated the greatest benefit would be in the transfer of heating, ventilation, and air conditioning (HVAC), electrical cableways, and critical path network scheduling data. One area which is gaining more interest is the use of raster images for the exchange of drawings. The decision to proceed with the exchange of HVAC and cableway data has not yet been made.

7.1 HVAC

Both shipyards use the standard parametric set of "Bath" shapes[7]. Initially, the shipyards would exchange the parameters of the shapes. The second phase of HVAC data transfer would include the complete geometric description. The shipyard would then be able to extract the parametric information from the structural product model instead of from an auxiliary file, enhancing the exchange of non-standard shapes.

7.2 Electrical Cableways

Initially the shipyards would exchange cable routing information using tabular data in text files. The second phase of electrical cableway data transfer would include the complete geometric description including hangars and individual conductors.

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7 A standard set of parametric shapes was developed by Bath Iron Works to define HVAC fittings. Most of the commercial and NAVY shipyards utilize these shapes whenever possible.

8 Lessons Learned

IGES can be used successfully to transfer drawings and models between dissimilar CAD systems. Nevertheless, it will require some support and a thorough understanding of the CAD and data transfer process. As with all software, some features do not work as well as expected and will require some enhancements and bug fixes by the CAD vendor. IGES was used successfully by the SEAWOLF program to transfer drawings, structural plates and shapes, and piping models.

The parties involved in the development of the product models must be involved in the development of the data transfer procedures. There is much more involved in the transfer of data than the selection of IGES as the neutral file format. This does not intend to minimize the criticality of the neutral file. The methods used to develop the CAD model must also be examined, and in some cases may have to be controlled by the procedures.

Test cases are critical to the success of a data transfer program. A combination of test cases taken from production as well as diagnostic test cases are required. Eventually, there will be a set of test cases available for diagnostics, however sample test cases taken from production should be included in the baseline for any end to end data transfer program.

Detailed, problem specific baseline tests must be created to fully test each release of CAD software and translators at each site. Discipline must be maintained throughout the life cycle of the exchange in order to maintain the translators and thoroughly test each change to either of the sites systems.

One of the key steps to resolving transfer problems in the early stage of the data transfer program was the involvement of the CAD vendors in the discussions. A CV representative and a an IBM Representative (for the CADAM system) was usually present at each meeting. This was important in order to ensure that bugs were repaired, and enhancements were
incorporated as soon as possible.

Data is not transferred between CAD systems, it is transferred between CAD

applications. For example, it is unrealistic to expect a structural CAD system to post-process an IGES file containing piping models.

When developing a data transfer program, select applications which have the highest payback potential.

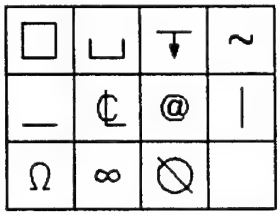
The exchange of graphic intensive data such as a drawing is much more difficult than the geometric model. This occurs because IGES allows graphics to be represented in many ways. Geometry is usually well defined mathematically, whereas graphics requires more interpretation by the developer of the IGES translator.

The exchange of geometry can be exchanged using full IGES or a subset. The exchange of the product model requires an Application Protocol. The transfer of drawings would probably have been easier if an Application Protocol had been available. In the case of the piping models, the exchange would have been impossible using subsets alone.

Appendix A - Listing of SEAWOLF Drawing Exchange Restricted Use Entities

Newport News Shipbuilding

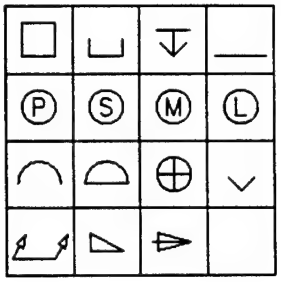
01 Text boxes created using the vertical bar character.
02 Mirrored text.
03 Detail pages which are dittoed once.
04 Engineering, section arrow, and font symbols.
05 CADAM special characters.



06 Breakout symbol.

Electric Boat

01 Mirrored Text
02 Feature Control Symbols.



03 Line fonts other than SOLID, DASHED, CENTERLINE, and PHANTOM.
04 Layered subfigures.
05 PCWIDTH lines.

Appendix B - Listing of SEAWOLF Drawing Exchange Prohibited Entities

Newport News Shipbuilding

01 Points without attribute data.
02 Unlimited lines.
03 "NO SHOWED" information except for noshow witness lines.
04 All geometry, test, and dimensions outside the drawing boundaries and non-viewable in the CRM hard copy.
05 Empty views.
06 Empty details.
07 Detail pages which are not dittoed.
08 "NC lines" except when used to establish plot data.
09 Dimensions with zero length leaders.

Electric Boat

01 Spline
02 Blanked entities.
03 Figures prepped in mode other than mode created.
04 Drawings with no views or draw mode entities.
05 Annotation outside the drawing boundaries and non-viewable in the CRM hard copy.
06 Empty subfigures.
07 Uninstanced subfigures.
08 Empty views.

Appendix C - Listing of SEAWOLF Drawing Test Cases

Newport News Shipbuilding		Electric Boat	
Number	Description	Number	Description
01	Obsolete	01	Sample Entities #1
02	Text	02	Sample Entities #2
03	Standard Dimensions	03	Obsolete
04	ISO Dimensions	04	Piping Drawing
05	Multiple Views	05	Ventilation Drawing
06	Obsolete	06	Fluid Diagram
07	Obsolete	07	Mechanical Drawing
08	Symbols	08	Obsolete
09	Section Areas	09	Multiple Views
10	Not Available	10	Interval Blanking
11	Lineweights	11	Dimensions
12	Characters	12	Fonts
13	Textboxes	13	Obsolete
14	Fills	14	Characters
15	Details	15	Crosshatching
16	Splines		

Appendix D - Listing of SEAWOLF Structural Test Cases

Newport News Shipbuilding

Number	Description
01	Single Stiffener
02	Bulkhead

Electric Boat

Number	Description
01	Common Test with NNS
02	Small Model
03	Large Model

Appendix E - Listing of SEAWOLF Piping Test Cases

Newport News Shipbuilding		Electric Boat	
Number	Description	Number	Description
01	Straight Pipe	01A	Loose Pipes - Angled
02	Pipes with Bends	01V	Loose Pipes - Vertical
03	Components	01H	Loose Pipes - Horizontal
04	Simple Configuration	02	Bent Pipes
05	Segmented Configuration	03	Loose Fittings (Not Exchanged)
06	Piping SCD	04	Piping Systems
		05A	Simulated SCD
		05B	Simulated SCD
		05C	Simulated SCD
		05D	Simulated SCD
		06	Complete Piping System

Appendix F - References

[1] Automated Interchange of Technical Information, Military Standard MIL-STD-1840A Notice 1. OSD CALS Policy Office, 1988.

[2] Initial Graphics Exchange Specification (IGES), Version 5.0, NISTIR 4412, National Institute of Standards and Technology, September 1990.

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[4] Wooley, D.J. and Manix, M.L., Development of an Initial Graphics Exchange Specification Capability, Journal of Ship Production, November, 1987.

[5] Digital Product Data Control Manual, DPMC-007, Naval Sea Systems Command, October 1989.

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[7] Manual Describing Content and Format of Plate and Rolled Section Structural Transfer, DPMS-004, Naval Sea Systems Command, October 1989.

[8] Piping Data Exchange Procedure, DPMP-005, Naval Sea Systems Command, March 1990.

[9] Palmer, Mark, E., Reed, Kent, A., 3D PIPING IGES APPLICATION PROTOCOL VERSION 1.0, National Institute of Standards and Technology, November 1990.